Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
L1	1	(instructional adj system) and (analysis adj template)	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2004/12/07 11:49
L2	0	(developing adj instructional adj system)	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2004/12/07 11:50
L3	2	(developing adj training adj system)	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2004/12/07 11:55
L4	160587	(creat$2 or generate or develop) and (job or activities) and (analys$2 or diagnos$2) and (template or form or questionnaire)	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2004/12/07 12:56
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L6	85	(creat$2 or generate or develop) and (job or training) and (analys$2 or diagnos$2) and (template or form or questionnaire) and (rule adj base) and (webbase or web) and pars$3 and (course or curriculum)	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2004/12/07 14:56
L7	2	(job adj training) and (analysis adj template)	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2004/12/07 14:57
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L9	1	(job adj training) and (performance adj tool)	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2004/12/07 14:58

L10	1048	(performance adj tool)	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2004/12/07 14:58
L11	3	(performance adj tool) and (rule adj base)	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2004/12/07 14:58
L12	33	(job adj training) and (rule adj base)	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2004/12/07 14:58
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L14	73	(job adj training) and @pd<"20000612"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2004/12/07 15:38
L15	3	(job adj training) and (rule adj base) and @pd<"20000612"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2004/12/07 15:39

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REUSABLE LEARNING AND INFORMATION ATOMS APPROACH TO WEB-BASED EDUCATION

V. Uskov* and M. Uskova**

Abstract

Traditional academic and training courses are built as large, monolithic structures that are (1) non-flexible, (2) difficult to repurpose into searchable self-paced objects, and (3) fixed in length, sequence, and scope. The traditional *instructor-led* model of learning does not address the need for similar knowledge and skills to be taught on self-paced, media-driven platforms such as Web-based learning and Web-based training. The innovative *reusable learning objects* (RLOs) approach addresses this problem. An online course that is built-on RLO strategy (1) is very flexible to timely updates, modifications, adaptation, and customization; (2) strongly supports competency-based, customized, personalized types of e-learning and e-training; and (3) gains a "value-add" that in most cases will pay off many times over (in terms of learning effectiveness, development time, costs, etc.). This research article attempts conceptually and systematically to describe a hierarchy and modularity (granularity) of learning sequences, learning activities and actions, RLOs and resuable learning atoms, and reusable information atoms. The premise is that later on those conceptual modular models can be formalized in the form of working programme models (e.g., agent-based models) and used by various Web-based education (WBE) systems, providing increased effectiveness and efficiency of both WBE-related instructional design, and teaching and learning processes.

K y Words

Learning objects, learning atoms, information atoms, learning activities

1. Introduction

Modularity (granularity) is the foundation for a design and development of Web-based education (WBE) courseware. Using this principle, designers of online degree programme will be able to easily and quickly assemble various appropriate curriculum from online courses. Designers of academic or training courses can put together a new programme or course by quick integration of available online content building blocks—reusable existing online classes, lessons, and modules—by using various models of learning sequences (LSs) and learning activities (LAs). Online classes and lessons can be constructed from online libraries of standardized learning objects and information objects, such as texts, pictures, images, figures, graphics, tables, essays, video clips, sound recordings, advanced animations, etc. [1].

Reusable learning objects (RLOs) approach [2–6] is one of the most promising technologies of choice in the next generation of instructional design, development, and delivery, due to its great potential for reusability, generativity, adaptability, scalability, customization, and personalization [1, 7–9].

This article attempts conceptually to describe an approach based on active utilization of RLOs and reusable learning atoms (RLAs), reusable information atoms (RIAs) and granularity of LSs, LAs and actions. The premise is that the developed conceptual modular models of learning content and LSs later can be formalized in the form of working programme models (e.g., agent-based models) and used by various learning management systems (LMSs) and authoring tools for e-learning and e-training.

2. Hierarchy of Learning Content

The following definitions will be used in this article. An online course is a sequence of learning experiences enabled by a course designer/instructor and pursued by learners. An online course consists of classes, and each class consists of lessons. Each class and/or lesson is a collection of learning objects and LAs aimed to accomplish one or several of the sub-goals of the online course. In many ways, an online class is a miniature online course requiring its own objectives, welcomes, introductions, assessments, and feedbacks. Based on the given definitions, we will use the following hierarchical structures of *learning content* (Fig. 1):

- Curriculum (Degree Programme or Training Programme),
  - Courses,
    - Classes,
      - Lessons or Reusable Learning Objects (RLOs),

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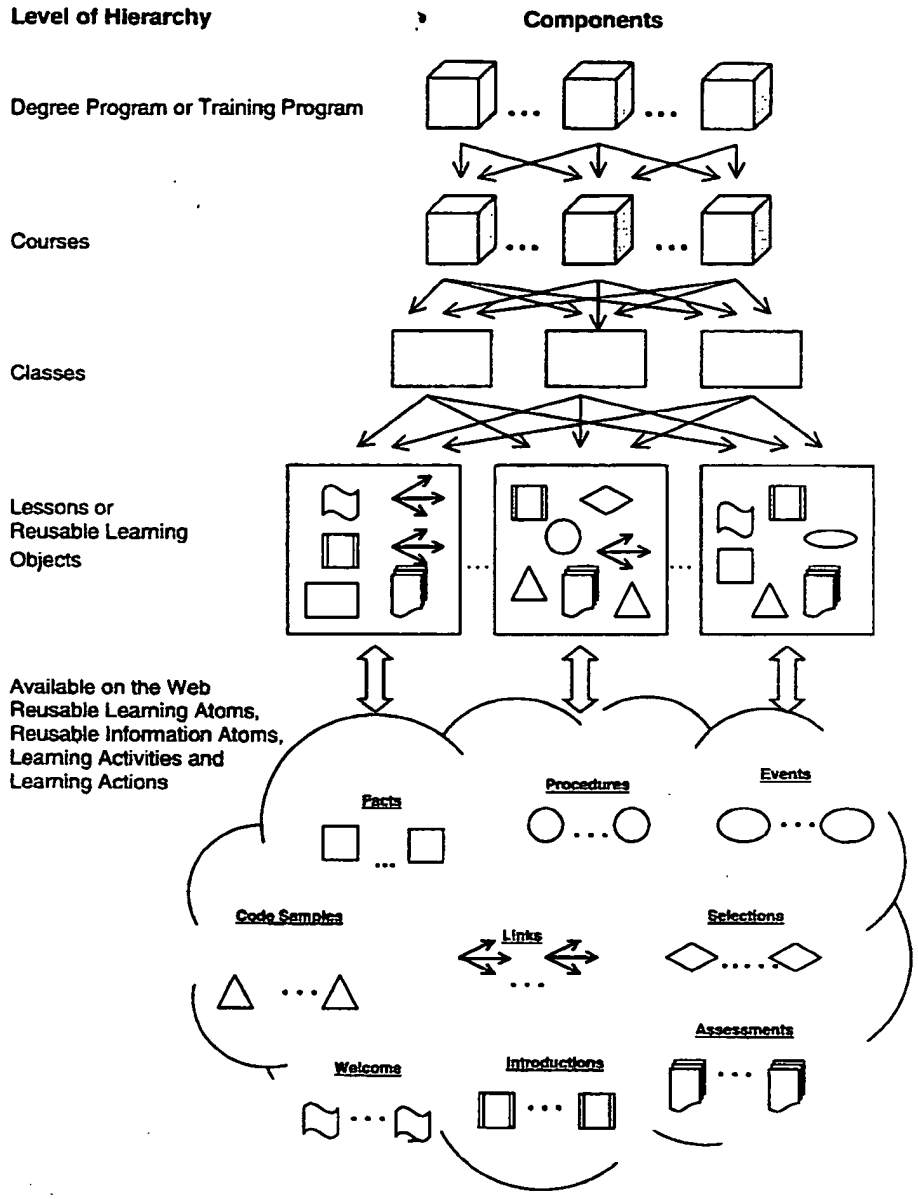

Figure 1. Hierarchy and modularity of learning content.

- Reusable Learning Atoms (RLAs),
- Reusable Information Atoms (RIAs).

and *learning process*:

- Learning Sequences (LSs),
- Learning Activities (LAs),
- Learning Actions.

3. Reusable Learning Objects and Atoms, and Information Atoms

3.1 Existing Definitions of RLO

To facilitate the adoption of the learning objects approach, the Learning Technology Standardization Committee (LTSC) of the Institute of Electrical and Electronics Engineers (IEEE) was formed in 1996 to develop and promote instructional technology standards [2]. Without such standards, producers of learning content would have no way of assuring the interoperability of their instructional technologies, specifically, their learning objects. A definition of a learning object proposed by the IEEE LTSC [2] is as follows:

Learning objects are defined as any entity, digital or non-digital, which can be used, re-used or referenced during technology supported learning. Examples of technology-supported learning include computer-based training systems, interactive learning environments, intelligent computer-aided instruction systems, distance learning systems, and collaborative learning environments. Examples of learning objects include multimedia content, instructional content, learning objectives, instructional software and software tools, and persons, organizations, or events referenced during technology supported learning [3].

It is good to mention here that several well-known initiatives and/or projects develop their own technical definitions of learning objects and technical standards to support the broad deployment of learning objects, for example, the Alliance of Remote Instructional Authoring and Distribution Networks for Europe (ARIADNE) [4], the Instructional Management Systems (IMS) Project (including corporate members such as Microsoft, Oracle, Sun, Macromedia, Apple, IBM, UNISYS, the US Department of Defense, the US Department of Labor, the California State Universities, International Thompson Publishing, and Educational Testing Service) [5], Advanced Distributed Learning (ADL) Project and its SCORM Model [6], and several other projects.

3.2 RLO's Definition to Be Used

In this work, the following working definition of RLO will be used: "RLO is any digital resource that can be reused to support Web-based learning" [9–11]. This definition includes anything that can be delivered across the network on demand, be it large or small. Examples of RLOs may include live or prerecorded video or audio fragments, pieces of text, animations, graphics, Web-based applications, software applications, Web pages, and other pieces that are aimed to deliver complete piece of knowledge to a learner.

3.3 "Ideal" RLO

The WBE environment must permit scalable contextualization so that learners can control the extent to which context is presented with RLOs' content. Therefore, the "ideal" RLO for WBE in which context is scalable and adaptive, should be [12]:

1. modular, free-standing, and transportable among various Web-based applications and learning environments
2. able to satisfy a single (non-dividable) learning objective
3. accessible to various online audiences (i.e., easily adaptable to audiences beyond the original target audience)
4. coherent and unitary within a predetermined schema so that a limited number of metatags of metadata can capture the main idea or essence of the content, and maximize RLOs' effectiveness and efficiency
5. not embedded within particular formatting so that it can be repurposed within a different Web-based learning environments (e.g., with different technical platforms and visual schemas without loosing the essential value or meaning of its components—text, data, graphics, animations, video, audio, or images).

3.4 RLO's Structure to Be Used

The above-mentioned definition of an RLO is supported by the proposed RLO's conceptual model (structure) that is based on the idea that an RLO is a collection of RLAs

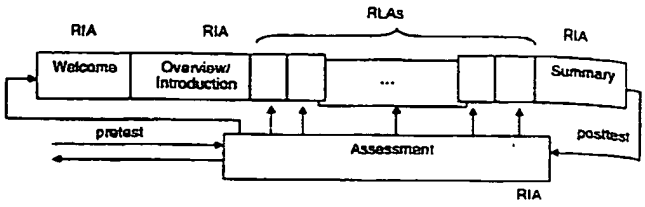

Figure 2. A conceptual model (structure) of an RLO.

that are grouped together to teach a common task based on a *single learning objective* [13]. In order to convert the collection of RLAs into a complete *learning experience—a lesson* or RLO, four other RIAs, specifically, *Welcome RIA*, *Overview or Introduction RIA*, *Summary RIA*, and *Assessment RIA*, are added to a set of RLO's RLAs (Fig. 2).

An RLA is an elementary non-dividable piece of learning that is built upon a single learning objective. Each RLA can be classified as either being a concept, fact, process, or procedure. RLA's content may be of three possible types, specifically: (1) content items (e.g., pieces of learning), (2) practice items (e.g., learning actions), and (3) assessment items (e.g., tests, quizzes, and exams).

An RIA is an elementary non-dividable piece of information that is built upon single information objective. The *Welcome RIA* contains only one content item—Greetings. The *Overview/Introduction RIA* may contain up to seven different content items, such as (1) Overview, (2) Introduction, (3) Importance, (4) Goal and Objectives, (5) Prerequisites, (6) Scenario, and (7) Outline. The *Summary RIA* may contain several content items such as (1) Review, (2) Next Steps, and (3) References/Links/Additional Knowledge Resources.

The *Assessment RIA* usually serves two main functions, specifically:

1. *pretest*: tests learners initial knowledge, determines gaps in knowledge and skills prior taking the "lesson", and indicates which RLAs fill those gaps;
2. *posttest*: ensures the learner has achieved mastery on all objectives for a given "lesson"; determines gaps in knowledge and skills after taking the "lesson" and indicates which RLAs learners should review.

3.5 Examples of RLAs and RIAs

A brief summary of possible types of RLAs and RIAs [14–18] that are appropriate for Web-based learning and training are given in Tables 1 and 2.

Based on the proposed conceptual models of RLO, RLA and RIA, a fragment of the C++ course structure with several RLOs and corresponding RLAs and RIAs may look like in Table 3.

3.6 Assessment RIA

Different types of assessment RIAs should be supported by the online assessment engine—generator of test questions

Table 1
Types of Reusable Learning Atoms Relevant to Web-Based Education

Type of RLA	RLA's Description/Function
Web-based knowledge resource	Provides pointers and hyperlinks to information on the Web the learner may need before, during, and/or after taking a particular lesson
Concept, statement, fact, featured example (that are available on the Web)	Presents a Web-based description of a single example or case study along with commentary about it (a picture, an image, a concept, a principle, a statement, an event, a phenomenon, a system, etc.)
Code sample (that is available on the Web)	Demonstrates a self-contained self-executable hyperlinked fragment of a programming or scripting language that can be executed on the Web, for example, using a sharing Web-based application (the example is given on Fig. 3)
Prerecorded video and/or audio fragment (that are available on the Web)	Lets learners to review a previously recorded live event in online mode, for example, video lecture using streaming video and audio technologies, chat session, bulletin board, etc. (the example is given on Fig. 3)
Explanation of a procedure or activity	Provides clear instructions on how to do or execute a given fragment, task, code, etc., for example, HELP system, HOW-TO-USE systems, etc.
Web-based automated learner feedback	Invites learners to evaluate the effectiveness of the online lesson and to suggest improvements using online evaluation tools and automatically deliver learner's feedback to instructor using either anonymous or named messages

Table 2
Types of Reusable Information Atoms Relevant to Web-Based Education

Type of RIA	RIA's Description/Function
Welcome	Greets the learner, tells what the online lesson is about, and makes clear why the learner should take it (an example is given on Fig. 4)
Class and/or module overview	Provides hyperlinked general information about RLO's goal, objectives, list of topics, learning procedures/functions/methods to be used, Web-based knowledge resources, and anticipated outcomes
Introduction to a class or module	Establishes the subject and characteristics of the online lesson and prepares the learner to begin the Web-based LAs
Summary and/or conclusion	Recaps the important ideas of the online lesson, proposes the next possible steps of learning
Assessment	A collection of online assessment items. In this case, each assessment item is a question or measurable Web-based activity used to determine if the learner has mastered the learning objective for a given RLO

and/or problems of various types, for example (1) "true and false" tests, (2) "multiple choice" tests, (3) "matching-type questions" tests, (4) "drag and drop" tests, (5) "hot spot" tests, (6) "fill-in the blank" tests, and (7) "essay" tests. A rational for utilization of one of available types of test questions/problems is usually dictated by (1) RLO's objective and (2) what the learner is required to remember or to do in order to demonstrate mastery of a given RLO. In other words, it is necessary to identify an appropriate cognitive level that identifies how learner will remember or use the skills and knowledge he/she is acquiring by taking a given RLO. A particular method of classifying cognitive levels could be based either on (1) Dr. Merrill's taxonomy [19], specifically (a) *Remember* and (b) *Use*; or (2) Dr. Bloom's taxonomy [20], specifically, (a) *Knowledge*, (b) *Comprehension*, (c) *Application*, (d) *Analysis*, (e) *Synthesis*, and (f) *Evaluation*.

3.7 RLO's Metadata and Characteristics

In order to compose automatically and dynamically various specific RLOs from a database of RLAs and RLOs, or, more generally, generate a personalized or customized LS

Table 3
A Fragment of Online Course's Structure That Is Based on Proposed RLOs, RLAs and RIAs

Class #	RLO's Title	RLA or RIA #	Titles of RIAs and RLAs	Approximate Duration (min) of RIA or RLA
1	Introduction to Programming	1	Lesson's Pretest	15
		2	Welcome—Introduction—Overview	15
		3	Basic Definitions	30
		4	Steps to Create a Program	30
		5	C++ Basics—The Hello World Program	30
		6	Lesson's Posttest	20
		7	Homework Assignment 1	30
2	Numerical Processing I	1	Lesson's Pretest	15
		2	Welcome—Introduction—Overview	15
		3	Defining Variables	30
		4	Assignment and Input Operations	30
		5	Output and Math Operations	30
		6	Complex Formula and Floating Point Output	30
		7	Lesson's Posttest	20
		8	Homework Assignment 2	30
3	Numerical Processing II	1	Lesson's Pretest	15
		2	Welcome—Introduction—Overview	10
		3	Complete Integer and Floating Point Data Types	30
		4	Principles of Data Conversion	30
		5	Mixed Mode Math	30
		6	Additional Operators	30
		7	Lesson's Posttest	20
		8	Homework Assignment 3	30
4	Decisions	1	Lesson's Pretest	15
		2	Welcome—Introduction—Overview	10
		3	Basic If-Then-Else Structure	30
		4	Compound Test Conditions	30
		5	Boolean Data and Conditional Expression	30
		6	Precedence of Operators and Testing of Floating Point Numbers	30
		7	Lesson's Posttest	20
		8	Homework Assignment 4	30

of RLOs, the LMS of WBE must have access to an online database with instructional design information to support the decision-making process on "sequencing" the RLOs. As a result, each RLO must be tagged with *metadata*—data about data—that further describes its attributes, functions, and associated RLAs and RIAs. Due to various drafts of standards [3, 21–24], RLO's metadata should include RLO's (1) title, (2) level objectives, (3) major

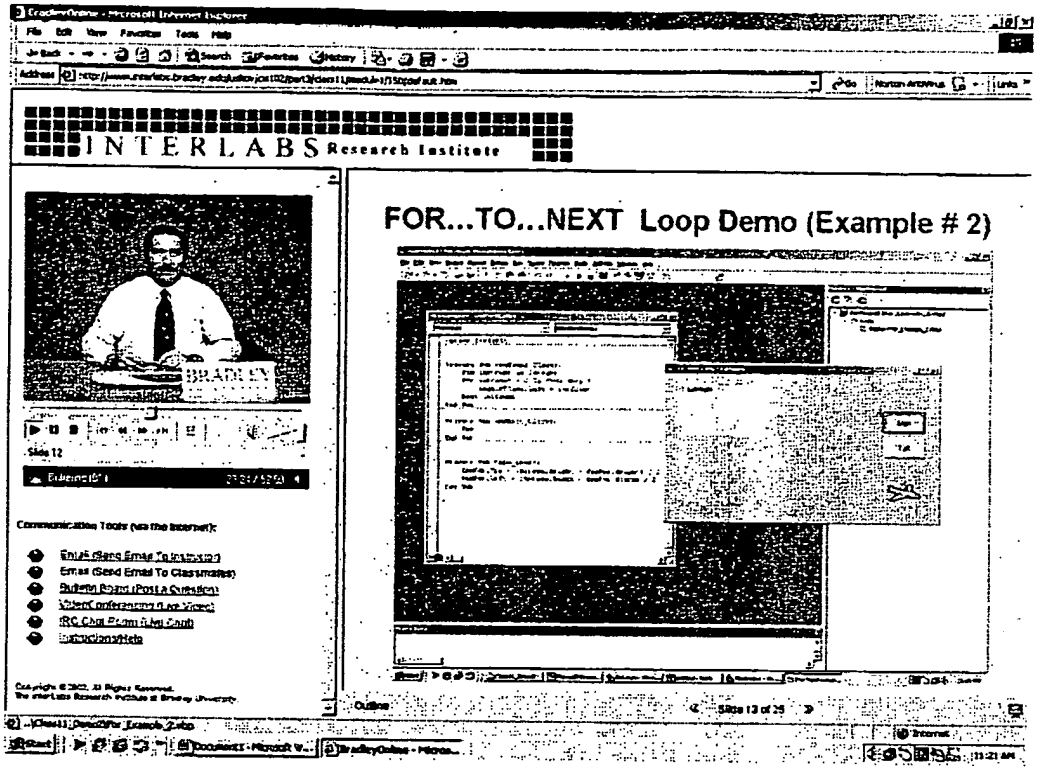

Figure 3. The example of the "Code sample" RLA that is available on the Internet (Bradley University, Computer Science and Information Systems Department, http://www.interlabs/bradley.edu/uskov/cis102/part3/class11/module1/150/default.htm).

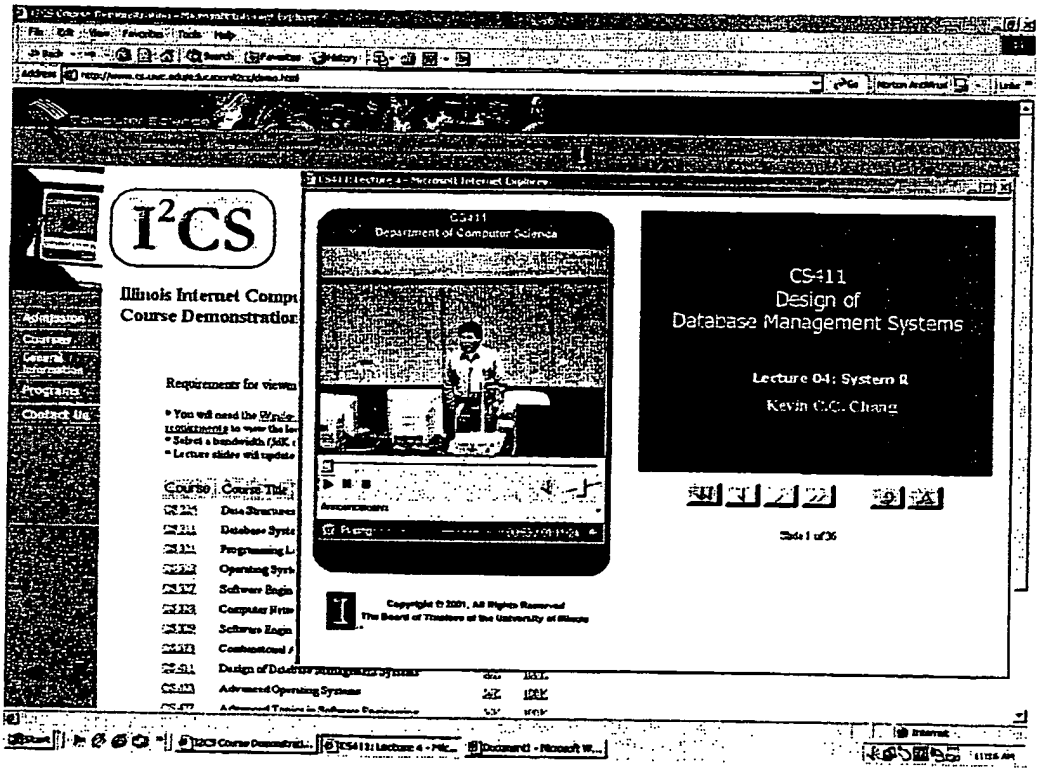

Figure 4. The example of the "Welcome" RIA that is available on the Internet (Demo of the Illinois Internet Computer Science Program, University of Illinois at Urbana – Champaign, Computer Science Department, http://www.cs.uiuc.edu/education/i2cs/demo.html).

topic areas, (4) learning objectives, (5) name of designer, (6) name of knowledge source, (7) date of creation, publication date, expiration date, and date of last modification, (8) used language (either natural or programming), (9) list of prerequisites, (10) needed technical platform, technology or equipment, etc.

However, due to the results of performed research, several other fundamental characteristics of RLOs have been proposed in order to increase the reusability, efficiency and effectiveness of RLOs, for example:

1. *number of RLAs and RIAs combined*—describes the total number of individual RLAs and RIAs (such as video clips, images, etc.) combined in order to create an RLO;
2. *type of RLAs and RIAs contained*—describes the types of RLAs and RIAs that have been used to compose an RLO;
3. *reusability of constituent RLAs (RIAs)*—describes whether or not an RLO's constituent RLAs (RIAs) may be individually accessed and reused in new learning contexts;
4. *type of use*—describes the manner in which the RLO is generally used;
5. *external dependence*—describes whether the RLO needs external information (e.g., knowledge resource on the Internet or intranet) about RLOs other than itself;
6. *algorithms and procedures*—describes algorithms and procedures that are implemented in an RLO;
7. *contextual reuse*—describes different learning contexts in which the RLO might be used, that is, the RLO's potential for reuse in different content areas, and other RLO's characteristics.

3.8 RLO's Creation Process

Usually, building RLOs requires several procedures. The RLA- and RIA-based approach requires at least the following design and development stages:

1. *planning/design stage* including (1) analysis of RLO's tasks; (2) identification of RLO's learning objectives and LAs; (3) creation and articulation of specifications for RLO's content; (4) identification of types of RLAs and RIAs to be used; (5) identification of hardware, software, and technologies to be used; (6) RLO's document templates; (7) RLO's metadata to be used; (8) editorial standards; (9) modularity requirements; (10) structural rules; (11) level of granularity desired; (12) RLO's accessibility and connectivity; (13) identification of assessment needs, etc.;
2. *development stage* including (1) development of constituent RLAs and RIAs; (2) development of assessment engine; (3) development of assessment items; (4) development of metadata, etc.;
3. *testing stage* including alpha and beta testing of RLO;
4. *evaluation stage* including different types of formative and summative evaluation of RLO's content, flexibility efficiency, effectiveness, impact on learners, mobility, accessibility, etc.

3.9 Contextualization Techniques

The key for deploying RLOs effectively is to provide ways for the learner to contextualize the information. Without context, RLOs can be confusing, misleading, or completely meaningless. Context is the second path for personalization of RLOs (after adaptive selection of appropriate RLOs based on individual needs). Providing the original context of a RLO will often be inappropriate (and in many cases defeats the adaptive purposes of breaking instructional material down into smaller objects). The main question is: How much context is enough? or, How can context be scalable in expanse and type, so that the learner can decide how much is needed? The advanced and sophisticated learning content delivery systems based on RLOs should be able to provide not only learning RLO's content, but relevant and meaningful context, as well. Several possible methods could be used to enable contextualization of RLOs, depending on the systems and technologies available and on the extent to which the learning content needs to be adapted to individual needs, for example, (1) tailored wrappers, (2) tailored context frames, (3) adding context links to objects, and (4) pattern templates.

4. Types of Learning Activities and Learning Actions

The proposed RLA- and RIA-based approach is supported by modular LSs, including LAs and learning actions.

4.1 Learning Activities

LAs are coordinated actions that exercise basic intellectual skills, through processes, and analysis techniques. But mere action is not an LA. Individuals learn by considering, researching, analysing, comparing, evaluating, organizing, synthesizing, discussing, testing, deciding, and applying ideas. LA might be as simple as a mouse click and as complex as entire physics experiment using a virtual laboratory or participation in one-to-many videoconferencing; however, the goal of all LAs is the same—to provoke exact mental activities that lead to learning and new knowledge [16]. Usually, LAs have three well-defined phases, each of which may involve several learning actions: (1) *prepare* (read and understand assignment; get required learning materials; if necessary, create a team/virtual community); (2) *learn/do* (perform core learning actions; get a meaningful result; test and explain the result; if necessary, re-do learning actions; discuss results with team members; submit your work); and (3) *analyse* (analyse what was learned; define ways to apply knowledge or skills).

Table 4
Types of Learning Activities Relevant to Web-Based Education

Type of LA	Description of LA
Web-based presentation	Learners watch, listen, and/or read carefully prepared explanations
Virtual laboratory	Learners repeatedly practice applying specific knowledge or a well-defined skill
Search of knowledge resources on the Web	Learners find reliable sources of knowledge or information on the Web (either Internet or intranet)
Guided research	Learners gather, analyse, discuss and report on a given task
Guided analysis	Learners analyse data to evaluate its validity, trends, and understand principles and concepts
Team design	Learners work as a coordinated team to produce a single design or to solve a complex problem
Brainstorming	Distributed learners (members of virtual learning community) work together to generate creative solutions to a problem or to accomplish some other goals
Case studies	Learners study a meaningful, detailed, well-explained example of a real-world event, process, or system to abstract useful concepts and principles
Role-playing scenarios	Learners adopt assigned roles (a leader of a team, a member of a team, etc.) in simulations involving complex interpersonal interaction
Group critiques	Learners receive and react to the criticisms from their peers. Learners submit a work that others in the class or virtual learning community critique
Virtual laboratory sessions	Learners conduct experiments with simulated/virtual laboratory equipment
Hands-on exercises	Learners perform a real task outside the class or lesson
Learning games	People learn by playing. Learning games are computer simulations (virtual reality) that let learners practice a highly interactive multimedia task

Examples [16–18] of several LAs that are appropriate for Web-based learning and training are given in Table 4. These LAs can be adapted to work with any subject matter. Many of them can be used in classroom or virtual learning community as a whole, by small teams, by individuals monitored by the instructor, and by learners working alone.

Multiple experiments, summative evaluations and learner feedback reports clearly demonstrated that the above-listed LAs easily adapted the proposed RLA- and RIA-based approach; for instance, the examples of (1) Web-based presentation, (2) virtual laboratory, (3) search of knowledge on the Web, (4) case study, and (5) hands-on exercise, LAs are used in the innovative CIS102 online course at Bradley University that is available at http://www.interlabs.bradley.edu/uskov/cis102.

4.2 Learning Actions

List of *learning actions* that are relevant to WBE may include but is not limited to the following actions: (1) present, (2) moderate, (3) direct, (4) observe, (5) summarize, (6) compare, (7) evaluate, (8) search, (9) ask, (10) answer, (11) read, (12) write, (13) play roles, (14) help, (15) call a conference, (16) send e-mail, (17) practice, and (18) take a test. A list of *learning media* that are based on LAs and appropriate for WBE include but is not limited to (1) Web page, (2) Web form, (3) Web document, (4) Web application, (5) chat, (6) audioconference, (7) videoconference, (8) discussion group, (9) bulletin board, (10) white board, (11) application sharing, (12) document sharing, (13) e-mail, and (14) newsgroups.

A list of *people* that are involved into LAs and learning actions may include but is not limited to (1) a learner, (2) an instructor, (3) a facilitator, (4) a class, (5) a team/group, (6) an administrator, (7) a librarian, and (8) a technician.

5. Types of Learning Sequences in Web-Based Education

One online course and/or online class may allow (1) only one LS, or (2) several different LSs for different type of learners [16]. A list of common LSs [14–18] that are appropriate for WBE and are based on active utilization of the proposed RLAs and RIAs is given in Table 5. Each LS can be applied to either online course or online class. Each LS may have multiple variations based on designer/instructor experience in WBE and personal-teaching style of online courses.

Table 5
Types of Learning Sequences Relevant to Web-Based Education

Type of LS	Description of LS
Traditional LS	After taking Welcome/Overview/Introduction RIA, learners proceed lesson-by-lesson (RLO-by-RLO) through a serious of online lessons. There are a Summary RIA and Assessment RIA (e.g., final exam) at the end of the LS
Online learner-customized LS	The online classes and/or lessons that are based on the knowledge, skills and/or choices/ preferences of individual learners. Each learner may select his/her specific path and set of RLAs and RIAs to learn. The path may rejoin and branch again before Summary RIA and Assessment RIA, which covers all topics, regardless of the branches taken
Knowledge-paced LS	After taking Welcome/Overview/Introduction RIA, learners proceed through a serious of Assessment RIA (tests) until they reach the limits of their current knowledge. Then they are either transferred (1) into the main flow of LS with N RLOs, which ends with Course Summary RIA and Course Final Exam RIA, or (2) directly into Course Summary RIA and Course Final Exam RIA (Fig. 5)
Web-based exploratory LS	Learners find knowledge on their own. Learners navigate the Web, available online classes, modules, documents, knowledge bases, Web sites, etc. in accordance with course-based designated hyperlinks in order to accomplish RLOs' specific learning goals. Once learners have accomplished all learning goals and passed all Assessment RIAs (tests), they view a Summary RIA and take a Course Final Exam RIA (Fig. 6)
Pretest-based LS	A pretest-based LS is generated in accordance with learner's answers to questions/problems in Assessment RIAs at the start of the online RLOs

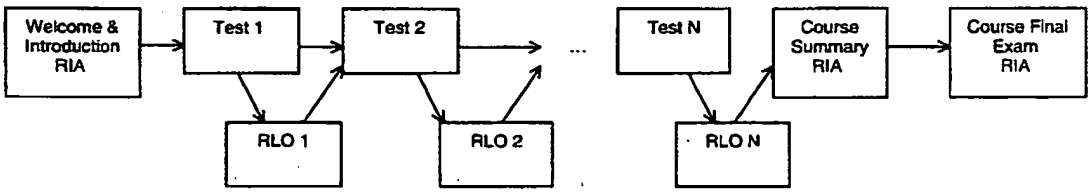

Figure 5. Conceptual model of knowledge-paced LS.

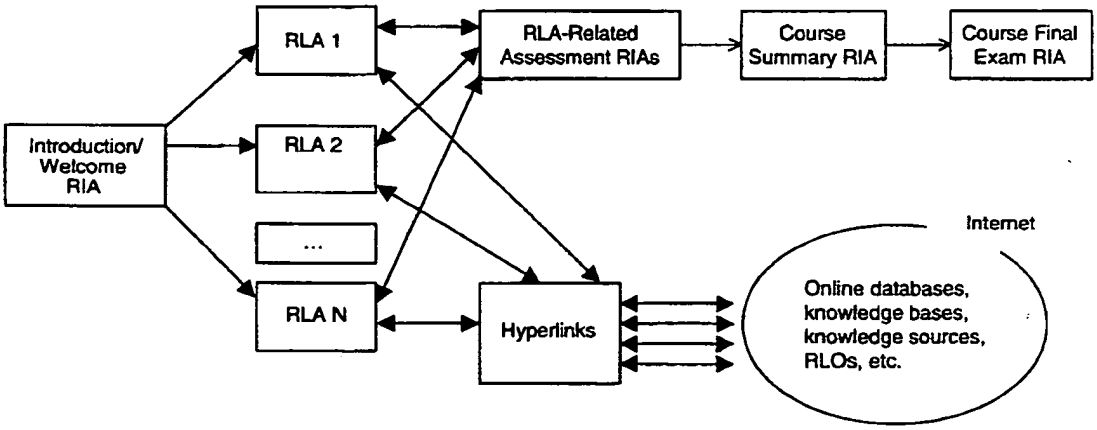

Figure 6. Conceptual model of Web-based exploratory LS.

6. Conclusion

The results of performed research and experiments clearly demonstrate the advantages of the proposed approach based on the active use of RLOs, RLAs, and RIAs in WBE system. Particularly, the main advantages of this approach include but are not limited to (1) flexibility in RLOs, RLAs, and RIAs utilization in various WBE systems by different developers of online content; (2) ease content-related searches on the Web and corresponding updates

of learning content; (3) adaptation, personalization and customization of RLOs, RLAs, and RIAs; (4) RLAs' and RIAs' interoperability; (5) RLAs' and RIAs' strong support of various types of learning and training such as (a) competency-based, (b) customized, and (c) personalized types; (6) easy management of learning content; and (7) significantly increased value of learning content.

On the other hand, the performed research identified several challenges due to acceptance of modular approach to build RLOs on the basis of RLAs, RIAs, and use of modular LAs and LSs. They include the following problems:

1. real-world knowledge is highly interrelated, and skills are interdependent; therefore, it is sometime difficult to present concepts in terms of separate learning modules/blocks, that is, RLOs, RLAs, RIAs
2. technical incompatibilities thwart reuse; therefore, it is necessary to develop standards for information exchange and RLOs, RLAs, and RIAs
3. RLOs, RLAs, and RIAs that are available on the Web have different styles of interfaces; therefore, it is necessary to follow common design standards for the user interface, visual appearance, and media usage, otherwise learners may be uncomfortable to use lessons and classes composed by dozens of different RLOs, RLAs and RIAs.

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Descriptors: *Computer aided instruction; Engineering education; Computer science; **Algorithms** ; Database systems; Computer architecture; Computer simulation; Students; Websites; Human computer interaction; Animation; Object oriented programming; Data structures
Identifiers: Computer science education; Collaborative learning; Production programming; Network administration; Programmable network sniffer; Classroom management; Multi-level online modules; Language-independent interactive data visualization; **Template** method **design** pattern; EiRev
Classification Codes:
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901 (Engineering Profession); 723 (Computer Software, Data Handling & Applications)
90 (ENGINEERING, GENERAL); 72 (COMPUTERS & DATA PROCESSING)

34/5/10 (Item 10 from file: 8)
DIALOG(R)File 8:Ei Compendex(R)

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Abstract: Traditional academic and training courses are built as large, monolithic structures that are (1) non-flexible, (2) difficult to repurpose into searchable self-paced objects, and (3) fixed in length, sequence, and scope. The traditional instructor-led model of learning does not address the need for similar knowledge and skills to be taught on self-paced, media-driven platforms such as **Web** -based learning and **Web** -based training. The innovative reusable learning objects (RLOs) approach addresses this problem. An online course that is built-on RLO strategy (1) is very flexible to timely updates, modifications, adaptation, and customization; (2) strongly supports competency-based, customized, personalized types of e-learning and e-training; and (3) gains a " **value** -add" that in most cases will pay off many times over (in terms of learning effectiveness, development time, costs, etc.). This research article attempts conceptually and systematically to describe a hierarchy and modularity (granularity) of learning sequences, learning activities